Fact Sheet (Web Content): Improving Energy Efficiency for Server Rooms and Closets

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Is there a ghost in your IT closet? If your building has one or more IT rooms or closets containing between 5 and 50 servers, chances are that they account for a significant share of the building’s energy use (in some cases, over half!). Servers, data storage arrays, networking equipment, and the cooling and power conditioning that support them tend to draw large amounts of energy 24/7, in many cases using more energy annually than traditional building loads such as HVAC and lighting.

The good news is that there are many cost-effective measures, ranging from very simple to more advanced, that can dramatically reduce that energy use, helping you to save money and reduce pollution. Some measures also “recapture” IT equipment and cooling system capacity, giving you headroom for additional IT equipment installations.

Top 14 Measures to Save Energy in Your Server Room or Closet

A) Simplest, No-Cost, or Very-Low-Cost Measures

1. Determine computational functions / Turn off any unused servers

An Uptime Institute survey suggests that close to 30% of servers are unused in data centers, with each one costing over $4,000 per year in energy, space, and maintenance costs, without adding business value. To save energy and important business resources, the following measures can be implemented on a regular basis to better manage server utilization.

- **Server Inventory and Application Mapping.** Create and regularly update a server hardware and application inventory to track the number of applications running on each server, and identify unused servers or servers with low utilization. These servers can then be consolidated, with some servers eventually turned off or reassigned. Depending on the level of complexity you desire, the inventory can be a simple spreadsheet or vendor-based software that automates the process.

- **Logical-to-Physical Server Tracking.** Because of the high volume of machines running in the server room, and the fact that server room operators may not be the users running the applications, it is easy to lose track of the connections between the systems/applications and the servers that run them. Having knowledge of these connections makes it easier for operators to track their equipment and its functions, and identify unused servers and redundant applications, thus further facilitating server management. Mapping these connections requires the same inventory tools described above as well as some information gathering from the application users.

2. Increase the air temperature at IT equipment inlet to 80 degrees

The American Society of Heating, Refrigerating and Air-Conditioning Engineers' **(**ASHRAE) Thermal Guidelines for Data Processing Environments recommend a temperature range of 64ºF to 80ºF for air cooling. This is the condition **at the inlet to the IT equipment**. Although this wide range may feel uncomfortable, it is endorsed by IT equipment manufacturers.

Raising the supply air temperature set point can enable significant energy savings -- especially if your cooling system features an economizer. The easiest way to track inlet temperature is to purchase a digital thermometer and stick it to the front of one of your racks. It's best to put it on the hottest rack, so try it in several places and adhere it at the hottest spot. Then, reduce the cooling in the room until the thermometer shows that temperature has raised to 80 ºF. Check it periodically with several measuring points, as your cooling needs may change over time, and the hottest spots may migrate depending on loads. There are also a variety of temperature data loggers that can help automate the monitoring process.

Note that the supply air temperature needed to cool the server room is closely linked to airflow management in the space; as airflow improves to minimize hot and cool air mixing (between supply and return air), the higher the supply air temperature can be and still meets the higher part of the recommended temperature range. See #4 for detailed descriptions on airflow management.

ASHRAE Data Center Environmental Condition Recommendations

Classes	Equipment Environmental Specifications				
	Dry-Bulb Temp (ºF)	Humidity Range, non-Condensing	Maximum Dew Point (ºF)	Maximum Elevation (ft)	Maximum Rate of Change (ºF/hr)
Recommended					
A1 to A4	64.4 to 80.6	41.9 ºF DP to 60% RH and 59 ºF DP			
Allowable					
A1	59 to 89.6	20 to 80% RH	62.6	10,000	9/36
A2	50 to 95	20 to 80% RH	69.8	10,000	9/36
A3	41 to 104	10.4 ºF DP & 8% RH to 85% RH	75.2	10,000	9/36
A4	41 to 113	10.4 ºF DP & 8% RH to 90% RH	75.2	10,000	9/36
B	41 to 95	8% RH to 80% RH	82.4	10,000	NA
C	41 to 104	8% RH to 80% RH	82.4	10,000	NA

Source: ASHRAE's "2011 Thermal Guidelines for Data Processing Environments"

For short periods of time it is acceptable to operate outside this recommended envelope and approach the extremes of the allowable envelope. All manufacturers perform tests to verify that their hardware functions at the allowable limits. For example, if during the summer months it is desirable to operate for longer periods of time using an economizer rather than turning on the chillers, this should be acceptable, as long as this period of warmer inlet air temperatures to the IT equipment does not exceed several days each year (otherwise the long-term reliability of the equipment could be affected). Operation near the upper end of the allowable range may result in temperature warnings from the IT equipment.

For more information, see ASHRAE's "2011 Thermal Guidelines for Data Processing Environments": http://www.eni.com/green-data-center/it_IT/static/pdf/ASHRAE_1.pdf. The recommendations in this 2011 white paper divided the data center equipment into four classes (A1 through A4). In this version, guidance was provided to determine the impact on reliability when operating A2 class equipment within its allowable range, i.e., 50 to 95 ºF. Generally following this guidance shows that operating in the allowable range for part of the year has an insignificant reliability impact.

For more information, see http://www1.eere.energy.gov/femp/pdfs/eedatacenterbestpractices.pdf.

3. Examine power backup requirements (do you really need UPS equipment and dual power supplies, and if so, how much is enough?)

Redundant equipment in the power delivery chain increases capital cost and consumes additional energy, as power conversions create heat which must then be removed. Not all IT equipment needs backup power; for example, some applications can simply be restarted without significant adverse effects when an electrical power disruption occurs. Some applications failover to other

IT equipment, so dual individual power supplies are not required. As these examples show, utility customers should analyze these systems to determine whether or not power conditioning or backup is needed; this helps to avoid costly redundant equipment that consumes additional energy.

Redundancy is sometimes provided for IT equipment power supplies, uninterruptible power supplies (UPSs), power distribution units (PDUs), or other transformers in the distribution chain. Any of these devices that provide power conversion from one voltage to another, or from alternating current to direct current or vice versa, have higher conversion losses (as a fraction of the power delivered) when they are lightly loaded, which is what occurs when redundant equipment is provided. More redundancy always equates to less efficiency, and should therefore be justified.

In addition, UPS and PDU sizing should be reviewed after hardware refresh or consolidation. If the consolidation reduces the overall IT equipment load, these devices may then become oversized with very poor efficiency.

Even when UPSs cannot be completely eliminated (e.g. when a UPS may be needed to bridge the startup time of a standby generator or allow an orderly shutdown), it is often possible to limit the level of redundancy to what is really required. For example a large 30-minute UPS for a rack and a 45-minute UPS for network may be the best thing for brownouts and ride-throughs, whereas a UPS per corded system would be overkill. Review uptime requirements, fault failover, and disaster recovery plans to determine appropriate UPS or redundancy requirements.

4. Airflow management: Install blanking panels, plug holes, install "chimneys", and consider airflow isolation measures

Airflow management is conceptually simple and surprisingly easy to implement. Your challenge: ensuring that the cool air from your cooling equipment gets to the front of your IT gear, without getting mixed up with the hot air coming from the back, or short-circuiting back to the cooling unit.

How do you get this done? In an ideal world the cold supply air would be directly ducted to your IT equipment, and the hot return air would be ducted directly back to the intake of the cooling unit(s). In practice, you only need to do one or the other, and there are interim improvements you can make that take far less effort. (See section 9 for a description of containment.)

For example, unused portions of IT racks act as airflow "short circuits"; cool air simply flows through the rack and back to the cooling units without having done anything effective.

The solution? Diagram and review the airflow. Check for cabling clutter and tight rack placement in an under-provisioned rack. Sketching out where air is coming from and going to and clearing up the path is simple, and it may eliminate overheating issues altogether. For some closets a $100 trip to the hardware store and a few hours of cleanup will make a big difference.

Next, install blanking panels -- cheap strips of sheet metal or plastic that block off unused portions of your racks. Don't let air bypass between or around the IT equipment.

Do you have an underfloor air distribution system in your server room? Be sure that all supply air comes out of the perforated or grate tiles in front of your racks, by plugging holes and blocking off power distribution units and other equipment that don't require direct cooling. Also check columns, cracks, and holes around the periphery of the raised floor. And about those perforations/grates: they should only be in front of racks where cool air can enter the front of IT gear, never in the back where the air will simply mix with hot exhaust before returning to the cooling units. It's fine for the hot aisle to be uncomfortably hot.

Also consider adding "chimneys" to your cooling units. These simple sheet metal extensions raise the return air intakes closer to the ceiling of the server room, where they can pull in only return air, not supply air. (Chimneys can impede access to cooling unit filters, though the filter units can be relocated to the top of the chimney, or access panels can be provided in the sides of the chimney.)

The airflow management techniques described above increase the effectiveness of other energy-saving measures, such as raising the supply air temperature (with hot/cold air mixing now minimized) and reducing the volume of air that is circulated by reducing fan speeds. These measures in turn provide higher temperature differential at the computer room air conditioners, leading to better heat exchange performance, which then improves the efficiency in the chilled water or refrigerant heat exchange. Thus, airflow management not only improves energy efficiency, it ensures that you can get the full cooling capacity from your system, avoiding the need for new cooling units prematurely.

B) A little More Complex, But Still Fairly Simple

5. Refresh the oldest equipment with high-efficiency versions

The energy efficiency of industry-standard servers improves dramatically from generation to generation, driven by customer concerns about the cost and availability of power in data centers. The latest servers deliver much higher "performance per watt" than three- to four-year-old servers do.

Establish server refresh policies that take into account increases in generation-on-generation energy-efficiency and power manageability improvements. The savings in energy and software costs can sometimes justify a faster refresh than expected. Purchasing high-temperature-tolerant servers can also save energy by reducing cooling needs.

Refreshing servers is a good opportunity to consider consolidation, as new servers usually have much more capacity than the ones they replace. When purchasing new equipment, servers with solid-state drives (SSD), rather than hard disk drives, may be considered, as they feature faster speeds, are generally considered to be more reliable, and consume less power.

Power supplies

Power supply efficiency is the output power divided by the input power. If a 700-watt power supply is 70% efficient, then it needs 1000 watts of input power to provide 700 watts of output power. The "lost" 300 watts is converted to heat, and so in addition to losing 300 watts of power, you have to provide additional cooling to remove the waste heat.

The 80 PLUS® certification for power supplies specifies efficiency levels at various loadings for both non-redundant and redundant internal power supplies. Most servers use redundant power supplies, and redundant power supplies typically operate at a less-efficient point on the efficiency curve. Be sure to specify the appropriate redundancy for your application and the highest level of efficiency that is economically reasonable for new server purchases.

80 PLUS Certification	115V Internal Non-Redundant			230V Internal Redundant			
% of Rated Load	20%	50%	100%	10%	20%	50%	100%
80 PLUS	80%	80%	80%	N/A			
80 PLUS Bronze	82%	85%	82%	---	81%	85%	81%
80 PLUS Silver	85%	88%	85%	---	85%	89%	85%
80 PLUS Gold	87%	90%	87%	---	88%	92%	88%
80 PLUS Platinum	90%	92%	89%	---	90%	94%	91%
80 PLUS Titanium	---	---	---	90%	94%	96%	91%

Source: http://www.plugloadsolutions.com/80PlusPowerSupplies.aspx

Specifying efficient power supplies with high efficiency (80 PLUS Gold or better) at their normal operating points can improve the efficiency of the power distribution chain by several percentage points. This also results in lower cooling requirements, producing further energy savings.

Power distribution and conditioning

Refreshing power distribution equipment (UPS, PDU) can also lead to substantial efficiency gains. Here are some important considerations:

- Select high-efficiency components (for example, refer to the upcoming Energy Star for UPS when it is available).
- Minimize power conversions: every power conversion (AC-DC, DC-AC, AC-AC, DC-DC) decreases overall efficiency and creates heat.
- Distribute higher voltage (e.g. 208v in lieu of 120v equipment may save 2-3.5% energy)
- Right-size your power distribution equipment: efficiency decreases when systems are lightly loaded.
- Review your need for redundancy and minimize redundancy levels.

Resources:

- Energy Star-qualified servers: www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DC
- Climate Savers Computing Initiative procurement requirements and product catalog: www.climatesaverscomputing.org/.
- Climate Savers Computing Initiative Power Supply Efficiency Requirements: http://www.climatesaverscomputing.org/csci-certification-output/technical-specs-2

6. Move to a more energy-efficient internal or external data center space, or to cloud solutions

Distributed server rooms are typically not very energy efficient. If a central data center is available, you may be able to save energy and reduce your utility bill, by moving your servers to that location. When an internal data center is not available, many organizations are moving their equipment to co-location or cloud facilities, which offer better security, redundancy, and efficiency than is typically available in small server rooms and closets.

It takes as much energy to cool and condition a typical server room as it does to run the servers themselves. As a simple example, the chart below shows representative data, assuming your server room contains 10 servers, with an average power consumption of 500W each, and that the cost of electricity is $0.01 per kilowatt-hour (kWh).

Space	Typical Room PUE	Server Power Consumption (10 servers), kW	Total Power Consumption (IT and Infrastructure), kW	Estimated Annual Energy Cost, $/year	Estimated Annual Savings if Moved to Data Center, $/year
Server Room	2	5	10	9,000	2,000
Converted Closet	2.5	5	12.5	11,000	4,000
Central Data Center	1.5	5	7.5	7,000	-

In the example above, although the computers are using the same amount of energy, the cost to power the room varies based on the efficiency of the cooling and power infrastructure. By moving gear to a central location, you not only save on operating costs every year, but also regain the space to use as an office or a conference room. Additionally, the data center space likely has a more robust infrastructure, which will keep your servers running in case of a power outage, cooling equipment failure, or other emergency.

There are, however, cases when moving the servers is just not possible. If that is the case, then use the information here to maximize efficiency of the server space.

7. Energy efficiency awareness training for IT custodial and facility staff

The staff responsible for operating and maintaining IT equipment in small server spaces are often not as immersed in the IT world as their counterparts in larger data centers. IT evolves rapidly and there are many advances to track. For this reason, server room operators should attend server room energy-efficiency awareness classes offered by utility companies, ASHRAE, and others. There are a lot of misconceptions around the powering and cooling of IT equipment, and communication and collaboration between IT and facility staff is essential.

For example, the air temperature entering IT equipment can be provided at 80 ºF or higher. But often in IT closets or small server spaces, temperature is read and controlled at a location in the room that has no bearing on the air entering the IT equipment, and consequently is set colder than necessary.

There are a number of resources available to assist in understanding energy efficiency options for data centers. Consult the following resources:

- Lawrence Berkeley National Lab (LBNL) - Benchmarking, case studies, best practices, demonstrations
  http://hightech.lbl.gov/datacenters.html
- U.S. Department of Energy (DOE) - DC Pro Assessment tools, case studies
  http://www1.eere.energy.gov/industry/datacenters/
- ASHRAE - Datacom book series, ASHRAE-DOE Awareness Training
  http://tc99.ashraetcs.org/

- ■The Green Grid - Web based resources http://www.thegreengrid.org/library-and-tools
- ■Pacific Gas and Electric (PG&E) - Best Practice Guidelines http://www.pge.com/hightech/
- ■U.S. Environmental Protection Agency (EPA) - Energy Star equipment http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency

C) More Complex, But Cost-Effective

8. Implement server power management

Enable Power Management Features if Possible. Modern IT equipment has many power management features which are sometimes disabled. Since some applications do not run continually, enabling power management saves energy effectively with low effort; this is especially true for storage equipment that is only accessed infrequently.

Implement Power Cycling. If servers are unused for long periods (hours at a time), a power-cycling system can be implemented to put unused servers in a light sleep mode (e.g., 1e system for "drowsy" mode).

Other Resources and Information. Check the Energy Star site for more information on enabling power Management. Also check with equipment vendors for specific design and features of power management of product models.

Remote Power Control. In addition, the ability to power-on a server remotely should be considered. Modern servers can be equipped with built-in (or add-on) cards, or after-market power-on adaptors, which allow system administrators to power servers on or off remotely. This remote power control may allow some under-utilized servers that would otherwise be running continuously to be switched off. In this case, an added benefit would be increased security, as systems not running cannot be attacked. This feature is also valuable when a server needs to be restarted remotely to restore functionality.

9. Consolidate and virtualize applications

Server rooms and closets typically run at low load levels (5-15% on average), while drawing 60-90% of their peak power. Servers draw a lot of power simply by being on. Consolidating multiple applications on a single server accomplishes the same amount of computational work, with the same level of performance, but with much less hardware (there may be just as many servers, but many will be virtualized onto other hardware), and therefore much lower energy consumption.

The most basic form of consolidation requires no virtualization software. Provided that the performance requirements of each application are well understood and modest (which is the case of most typical applications in small server rooms), and that they don't have conflicting software requirements (e.g., applications using two different versions of the same reporting software), you can consolidate multiple applications on a single server. More complex situations can be solved through virtualization, as covered below.

The simplest way to identify unused servers is to map applications to servers, as discussed in #1 above. Another way is to monitor server utilization. There are many Original Equipment Manufacturers (OEMs) and third-party solutions that offer monitoring functionality, from manual spot checks in the console to continuous monitoring and activity logging. Monitoring server utilization is a common best-practice in IT equipment management.

Before turning off "under-utilized" servers, find the task or machine owners. Determine the purpose for which the provisioning was intended (this prevents shutting down dedicated security, backup, or data compliance systems). Before shutting down the servers, ensure that the data archives and workload migration has occurred.

Server virtualization is a software solution that enables the hosting of multiple application workloads on a single physical server, with each workload running within its own operating system instance (aka, "virtual machine"). This prevents resource conflicts between workloads and can enable load balancing and failover between multiple machines. Virtualization reduces the number of physical servers required to run, considerably reducing the energy required to run applications.

Virtualization is a similar concept to consolidation, but it is implemented using a more sophisticated and flexible software solution. The separation of application workloads in their own virtual machines eliminates the risk of resource conflict and potential impacts on service availability. Virtualization works for the vast majority of applications, however there are situations where applications can only run on a certain set of systems due to hardware or security reasons. Major virtualization solutions provide means to check whether applications can be virtualized.

For more information on virtualization, see the Energy Star Server Virtualization web page.

10. Implement rack/infrastructure power monitoring, if possible

Power monitoring identifies the energy use and efficiencies of the various components in an electrical distribution system. Power meters can be installed at the panels serving the cooling units, or directly on IT and HVAC equipment. Another alternative is to read IT power from UPS display, and to estimate cooling power from the nameplate, taking into account unit efficiency and operating hours. Often power distribution products will have built-in monitoring capability; look for products with this feature when replacing equipment. When inefficiencies are detected, then steps can be taken to improve the system.

The main benefit of power measurement is to benchmark the server room such that the energy efficiency of the room can be compared with other server rooms through Power Usage Effectiveness (PUE) calculations, and the savings from future energy-efficiency measures can be evaluated. PUE and other metrics of the room can also be tracked over time to help identify operational problems and opportunities.

11. Install variable frequency drives on cooling units

If your server room is cooled with a Computer-Room Air Handler (CRAH) or Computer-Room Air Conditioner (CRAC) unit, then it is highly likely that the unit has a single-speed fan, and that it provides more airflow than your IT equipment needs. Units with variable frequency drives (VFDs) have the capability of providing only the amount of air that is required by the IT equipment.

Many CRAH unit manufacturers and others now offer retrofit kits for variable-speed fan drives that allow you to lower the airflow. If you are purchasing new cooling equipment, consider specifying units with variable-speed capabilities.

The implementation of airflow management measures and airflow isolation systems should be done in conjunction with the installation of a variable-speed drive on the cooling unit fan to maximize potential energy savings. See item 4 for air management suggestions.

12. Install rack/row level cooling

If you are installing a new server room or buying new racks, consider local cooling. Some infrastructure modification will be required, including chilled or cooling water piping.

In-rack cooling refers to a cooling system that is located within an individual server rack and only provides cooling to the contained rack, with the possibility of extending the cooling system to one or more adjacent racks. Often cooling water (sometimes refrigerant) is provided to cooling coils placed directly in the rack, and air is circulated by integral fans within that individual server rack (and possibly to one or more adjacent racks).

In-row cooling refers to a cooling system that is located to serve an individual row of server racks. Often chilled water (or sometimes refrigerant) is provided to cooling coils placed directly in or on the row of servers, and air is circulated by integral fans.

Rear Door Heat Exchangers (RDHXs) are a highly efficient option for cooling server racks. RDHXs involve installing a cooling coil directly on the rear (exhaust) section of the server racks. Cooling water (or refrigerant) is run through the coils to absorb the exhaust heat and provide the needed cooling. Air circulation through the cooling coil is provided by the internal server fans themselves; there are no external fans.

13. Use cooling systems with economizers, if practical

An air-side economizer simply draws in outside air for cooling when conditions are suitable - if it is less than 75 °F outside, why run the air conditioner?

If your server room is located on the building perimeter or in a single-story building, consider using a cooling system with an economizer feature to dramatically reduce energy use. This can be in the form of an exhaust fan at one location and an opening in another location that allows cool outside air to enter. Alternatively, it can be in form of a fan coil or CRAC/H with air side economizer capability. **Depending on the climate zone in which the server closet is located, this can save a significant amount of energy by reducing compressor cooling energy use.**

If you are able to improve airflow management sufficiently to have a 78 °F supply air set point, an economizer-equipped cooling system will use outside air for the majority of the year, depending on the climate conditions at your location. Many operators of utility-scale data centers are now building facilities that run only on outside air, sometimes supplemented with evaporative cooling.

Many existing server rooms are located in the interior core of buildings (especially in high-rise offices), so it can be difficult or impossible to use outside air for cooling, due to structural limitations. If you are designing or adding a new server room or closet, be sure to include a cooling system design that features economizers, to maximize energy efficiency.

14. Install a dedicated cooling for the room, rather than depending on building cooling

If your server room or localized data center relies on the building cooling system, it may make sense to install cooling equipment solely for the use of the room, so that the building system does not have to operate around the clock.

Many buildings rely on a central cooling plant that provides chilled water to a cooling loop. For many facilities, like office buildings, the cooling plant can be turned off overnight-, and on weekend- and holiday periods because there is no need to provide cooling at those times. However, if server room or localized data center cooling equipment draws from the same cooling loop, the central plant will have to operate continuously. Chillers, condensers, and circulation pumps will always be on, often at partial loading (which is where they operate at the lowest efficiency).

Installing dedicated cooling equipment (like a packaged air conditioning unit) for your server room(s) avoids this situation, and can result in significant energy savings. Specify a high-efficiency unit with a high SEER rating and 100% outside air capability. In addition, by setting a higher room temperature set point and disabling humidity control features, the dedicated unit can operate more efficiently.

Alternatively, server rooms running off a central Air Handling Unit (AHU) can be reasonably efficient if the air to all of the unoccupied spaces served by the AHU are turned off and the AHU has a variable-speed fan (these capabilities are common for modern variable-air-volume systems). If the server room is the only load on the AHU, the supply air temperature can be reset much higher than normal, greatly increasing the number of hours of compressor-free cooling over the year.

Glossary

- AHU: Air Handling Unit
- CRAC: Computer Room Air Conditioner
- CRAH: Computer Room Air Handler
- HVAC: Heating, Ventilation and Air Conditioning
- PDU: Power Distribution Unit
- PSU: Power Supply Unit
- PUE: Power Usage Effectiveness, a ratio comparing the total energy use for a data center (or server room) to the energy used solely by the information technology equipment.
- SEER: Seasonal Energy Efficiency Ratio
- SSD: Solid-State Drives
- UPS: Uninterruptible Power Supply
- VFD: Variable Frequency Drive
- VSD: Variable Speed Drive